SINP/TNP/2013/06, IPMU-13-0079

A natural scenario for heavy colored and light uncolored superpartners

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Abstract

Influenced by the current trend of experimental data, especially from the LHC, we construct a supersymmetric scenario where a natural dynamics makes the squarks and gluino super-heavy (order 10 TeV) while keeping the sleptons and the weak gauginos light (100-500 GeV). The dynamics relies on the interfusion of two underlying ideas: (i) gauge mediation of supersymmetry breaking with two messenger multiplets, one transforming as a triplet of weak SU(2) and the other as an octet of color SU(3); (ii) perturbative gauge coupling unification at the string scale even with these incomplete SU(5) multiplets. Interestingly, the relative magnitude of the triplet and octet messenger scales that ensures gauge unification at the two-loop level also helps to naturally keep the uncolored superpartners light while making the colored ones heavy.

If the recently discovered scalar particle with a mass of around 125 GeV at the CERN Large Hadron Collider (LHC) [1,2] has to be identified with the lightest supersymmetric (SUSY) Higgs boson then, within the framework of the minimal supersymmetric standard model (MSSM), the stop squarks are expected to be rather heavy (order 10 TeV) having a substantial mixing between their left and right components [3, 4]. Side by side, the non-observation of the first two generation squarks and the gluino in the 7 and 8 TeV run of the LHC, with the lower limits on their masses now pushed to around 1.5 TeV [5], sends us an early alert that they might remain elusive even in the 14 TeV run of the LHC. The absence of any statistically significant indirect evidence of new physics in meson oscillation and decays so far, measured with increasingly high precision by the Belle, BaBar and LHCb Collaborations, also endorses the view that colored superparticles might not lie within the periphery of the LHC territory. On the other hand, the uncolored superparticles, namely, the sleptons and the neutralinos/charginos, are (and would remain) relatively less constrained by the LHC [6, 7]. Interestingly, the (3.3-3.6)-σ deviation of the measured $(g-2)$ of muon [8] from its standard model (SM) expectation [9, 10] might hint towards a light smuon and gaugino/higgsino [11]. Additionally, the reported excess of the diphoton events in Higgs decay by the ATLAS Collaboration [12] can be explained by the presence of light staus [13–15] (though the diphoton decay rate reported by the CMS Collaboration [16] may not be construed as an excess). Even if these apparent discrepancies eventually disappear, the possible existence of light sleptons and weak neutralinos/charginos still merits a careful investigation especially in view of precision measurements at the upcoming International Linear Collider (ILC).

Given the present experimental situation as narrated above, what kind of a broad picture can we draw about plausible supersymmetric models? For example, can we conceive of a scenario that naturally accommodates heavy colored (order 10 TeV) and light uncolored (order 100 GeV) superparticles? This question is very pertinent and timely as in many scenarios, notably the gravity mediated supersymmetry breaking models, the heaviness of squarks also implies a set of heavy sleptons (*modulo* gaugino induced splitting by renormalization group (RG) running). Gauge mediated supersymmetry breaking (GMSB) models [17] offer a way-out by introducing messenger particles in the intermediate scale, well below $M_G \simeq 2 \cdot 10^{16}$ GeV, and at that scale the squark masses are generated being proportional to the strong gauge coupling and slepton masses are generated being proportional to the weak gauge coupling. Thus the masses of squarks and sleptons are split right at the time of generation and the relative separation between grows even further when those masses are run down to the weak scale. Note that in the minimal GMSB scenario one employs a Φ_5 and a $\Phi_{\bar{5}}$ messenger multiplets, which transform as a fundamental $\mathbf{5}$ and a $\bar{\mathbf{5}}$ representation of SU(5), respectively, for the generation of *all* superparticle masses. Still, it is difficult to keep sleptons too light if the squarks become too heavy.

In this paper, we resurrect an old idea in the GMSB context which introduces an unconventional choice of messenger particles [18]. One of the key features of this scenario is that the sources for squark/gluino and slepton/weak gaugino mass

generation are completely de-linked, which allows us to naturally maintain two orders of mass splitting between them. Instead of taking Φ_5 as $\Phi_{\bar{5}}$, here we employ messenger multiplets transforming as an adjoint octet (Σ_8) of color SU(3) and an adjoint triplet (Σ_3) of weak SU(2) [18]. The choices are not completely arbitrary as the origin of these states can be traced to the non-Goldstone modes of the scalar adjoint **24**-plet of SU(5). The superpotential of the messenger sector reads

$$W_{\rm mess} = (M_8 + \lambda_8 X){\rm Tr}(\Sigma_8^2) + (M_3 + \lambda_3 X){\rm Tr}(\Sigma_3^2)\,, \tag{1}$$

where the F-term vacuum expectation value (vev) F_X of the hidden sector superfield X transmits supersymmetry breaking to the observable sector via the messenger multiplets[1]. The following consequences deserve special attention:

(i) Even in the absence of complete SU(5) multiplets, the presence of an identical number of $\Sigma_3(\mathbf{1},\mathbf{3},\mathbf{Y=0})$ and $\Sigma_8(\mathbf{8},\mathbf{1},\mathbf{Y=0})$ messenger multiplets still ensures perturbative gauge coupling unification at a scale somewhat higher than M_G [20]. More specifically, if the masses of these states are around $10^{(13-14)}$ GeV, then unification occurs even with these incomplete multiplets at around the string scale $M_{\rm str} \approx 5\cdot 10^{17}$ GeV, which is the scale where the gravitational and gauge couplings are perturbatively unified [21]. This can be easily understood using the one-loop beta-functions of the gauge couplings. The gauge couplings at the string scale are given by

$$\begin{aligned}
\alpha_1^{-1}(M_{\rm str}) &= \alpha_1^{-1}(m_{\rm SUSY}) - \frac{b_1}{2\pi}\ln\frac{M_{\rm str}}{m_{\rm SUSY}}, \\
\alpha_2^{-1}(M_{\rm str}) &= \alpha_2^{-1}(m_{\rm SUSY}) - \frac{b_2}{2\pi}\ln\frac{M_{\rm str}}{m_{\rm SUSY}} - \frac{2}{2\pi}\ln\frac{M_{\rm str}}{M_3}, \\
\alpha_3^{-1}(M_{\rm str}) &= \alpha_3^{-1}(m_{\rm SUSY}) - \frac{b_3}{2\pi}\ln\frac{M_{\rm str}}{m_{\rm SUSY}} - \frac{3}{2\pi}\ln\frac{M_{\rm str}}{M_8},
\end{aligned} \tag{2}$$

where $b_i = (33/5, 1, -3)$ are the coefficients of the one-loop beta functions of the gauge couplings with MSSM particle content, and $m_{\rm SUSY}$ is the typical mass scale of the SUSY particles. To provide further intuition into the interplay of the messenger scale and the string scale (where gauge couplings unify), we use Eq. (2) to write (following the spirit of [22])

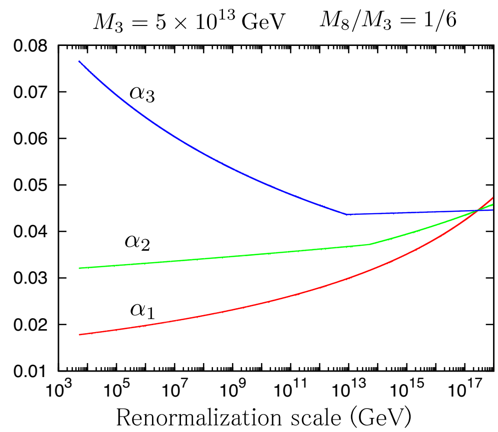

Figure 1: Unification of the gauge couplings with SU(3) octet and SU(2) triplet messengers with their masses at around 10^{13} GeV. Two-loop RG evolution has been used, and we have used $\alpha_S(M_Z) = 0.1184$ and $m_{\rm SUSY} = 5$ TeV.

$$(5\alpha_1^{-1} - 3\alpha_2^{-1} - 2\alpha_3^{-1})|_{m_{\rm SUSY}} = \frac{6}{\pi}\ln\left(\frac{M_{\rm str}^2 M_{\rm mess}}{m_{\rm SUSY}^3}\right)\,, \tag{3}$$

employing a common messenger scale $M_{\rm mess} \equiv M_3 = M_8$. Putting $\alpha_{1,2,3}^{-1} \simeq (57, 30, 11)$ at $m_{\rm SUSY} = 1$ TeV, we obtain

$$M_{\rm str}^2 M_{\rm mess} = M_G^3\,. \tag{4}$$

Eq. (4) points to two important things: (i) If the messenger scale lies two orders of magnitude below the GUT scale, then the scale of gauge unification, which is the string scale, hovers at one order higher than the GUT scale. (ii) Even with the same supersymmetric mass of Σ_3 and Σ_8, i.e. $M_3 = M_8$, the unification is always maintained. The splitting ($M_3 > M_8$) is necessarily realized when we require unification at the string scale by considering two-loop RG running of the gauge couplings. For instance, taking $M_{\rm str} = 5\times 10^{17}$ GeV and $m_{\rm SUSY} = 1$ TeV, one obtains $M_3 = 1.3\times 10^{13}$ GeV and $M_8 = 3.6\times 10^{12}$ GeV. In Fig. 1 we demonstrate this unification for $M_8 \simeq M_3/6 \simeq 5\times 10^{13}$GeV at the two-loop level.

(ii) The parameters M_8 and $\lambda_8 F_X$ control the squarks and gluino masses, while M_3 and $\lambda_3 F_X$ control the left-slepton and wino masses. Thus the masses of the colored and uncolored sector become completely independent. Moreover, since neither Σ_8 nor Σ_3 has any non-vanishing hypercharge, the bino and the right-sleptons are massless at this stage. A relatively small mass for them can be induced by gravitational interactions. Note that this de-correlation of masses has been achieved by the introduction of separate adjoint messenger multiplets responsible for the mass generation in

[1] For a recent discussion with a complete **24**-plet messenger multiplet transforming in the adjoint of SU(5), see [19].

the colored and uncolored sectors, *without* sacrificing the perturbative gauge unification. Moreover, for the unification to happen at the string scale, one must arrange $M_3 > M_8$, which helps to keep the left-sleptons lighter than the squarks. The elegance of this scenario thus lies in the interlinking of three issues, namely, perturbative string unification, the presence of intermediate scales characterizing gauge mediation, and the relative lightness (more specifically, two orders of magnitude) of uncolored sparticles compared to the colored ones, including the extreme lightness of bino and right-sleptons.

Let us now give a closer look into the superparticle spectrum. In our GMSB setup, the leading contributions to gaugino masses arising from the messenger loops are given by

$$m_{\tilde{B}} \simeq 0\,, \;\; m_{\tilde{W}} \simeq \frac{g_2^2}{16\pi^2}(2\Lambda_3)\,, \;\; m_{\tilde{g}} \simeq \frac{g_3^2}{16\pi^2}(3\Lambda_8)\,, \tag{5}$$

where $\Lambda_8 \equiv \lambda_8 F_X/M_8$, $\Lambda_3 \equiv \lambda_3 F_X/M_3$. Now, considering that $M_3 > M_8$ (discussed in gauge unification context), we tune λ_8 and λ_3 to ensure $\Lambda_8 \gg \Lambda_3$[2]. The soft mass-squared parameters of the squarks and sleptons are given by

$$\begin{aligned} m^2_{\tilde{Q}} &\simeq \frac{2}{(16\pi^2)^2}\left[\frac{4}{3}g_3^4(3\Lambda_8^2) + \frac{3}{4}g_2^4(2\Lambda_3^2)\right]\,, \;\; m^2_{\tilde{D}} = m^2_{\tilde{U}} \simeq \frac{2}{(16\pi^2)^2}\frac{4}{3}g_3^4(3\Lambda_8^2), \\ m^2_{\tilde{L}} &\simeq \frac{2}{(16\pi^2)^2}\frac{3}{4}g_2^4(2\Lambda_3^2)\,, \;\; m^2_{\tilde{E}} \simeq 0. \end{aligned} \tag{6}$$

For the generation of the bino mass we rely on Planck scale suppressed gravitational interaction between the supersymmetry breaking field X and the gauge kinetic function

$$\int d^2\theta\, c_X \frac{X}{M_P} W_\alpha W^\alpha + \text{h.c.}\,, \tag{7}$$

which also generates wino and gluino masses. The gravitino mass is generated roughly in the same order (slightly smaller than bino mass) and is given by

$$m_{3/2} = \frac{F_X}{\sqrt{3}M_P}\,. \tag{8}$$

We assume an universal gaugino mass $M_{1/2} \sim c_X 2\sqrt{3} m_{3/2} \sim 10 m_{3/2}$ at the unification scale $M_{\rm str}$. The lightest supersymmetric particle (LSP) turns out to be gravitino, which is the candidate for dark matter. We also assume a *sequestered* form of the Kahler potential, for simplicity, to ensure that tree level contributions to sfermion masses, like $X^\dagger X \tilde{f}_i^* \tilde{f}_j$, are hugely suppressed. The right-slepton masses are in fact generated during RG running and are essentially of the same order as bino mass at the weak scale ($m_{\tilde{E}} \sim 0.4 M_{1/2}$). Needless to say that the wino and gluino masses pick up additional messenger induced contributions during the RG running down to the weak scale.

In the present scenario, the higgsino mixing parameter $\mu \sim 6$ TeV, which follows from successful electroweak symmetry breaking. There are two important consequences for such a large μ: (i) due to a large left-right stau mixing, one of the staus can be very light, which helps us enhance (though moderately) the diphoton decay rate of the Higgs; (ii) for the muon $(g-2)$, the bino-smuon loop numerically dominates over the chargino-sneutrino loop. In the *left panel (a)* of Fig. 2, we exhibit the contours of the lightest stau mass $m_{\tilde{\tau}}$ and the Higgs to diphoton decay rate normalized to its SM value[3] $r_{\gamma\gamma} \equiv \Gamma(h \to \gamma\gamma)/\Gamma(h \to \gamma\gamma)_{\rm SM}$. Note that a (20-25)% enhancement of Higgs to diphoton decay rate can be accommodated. In numerical calculations, we have used the package `SuSpect` [23] with appropriate modifications to include the threshold corrections to the stau and sleptons from the chargino/neutralino and the heavy Higgs [24, 25]. The muon $(g-2)$ is calculated using `FeynHiggs` [26], for which we use the SM prediction as in [9]. The region below the blue solid line is excluded due to the vacuum stability constraint induced by the large left-right stau mixing [27–29]. This constraint puts an upper limit on $\mu \tan\beta$. In order to impose this constraint, we have used the fitting formula of [28]. In a more conservative approach, we have also drawn a blue-dashed line which corresponds to a relaxation of the upper

[2]If we impose the universality conditions, $M_3 = M_8$ and $\lambda_8 = \lambda_3$ at $M_{\rm str}$, then $\Lambda_8 \simeq \Lambda_3$ holds even at the weak scale since M_8/λ_8 and M_3/λ_3 are, to a very good approximation, RG invariant. However, we do not impose this universality as it does not lead us to the condition we require for unification, namely, $M_8 \sim M_3/6$.

[3]Since squarks, including the scalar tops, are super-heavy, the Higgs production cross section by gluon fusion is unchanged with respect to the SM.

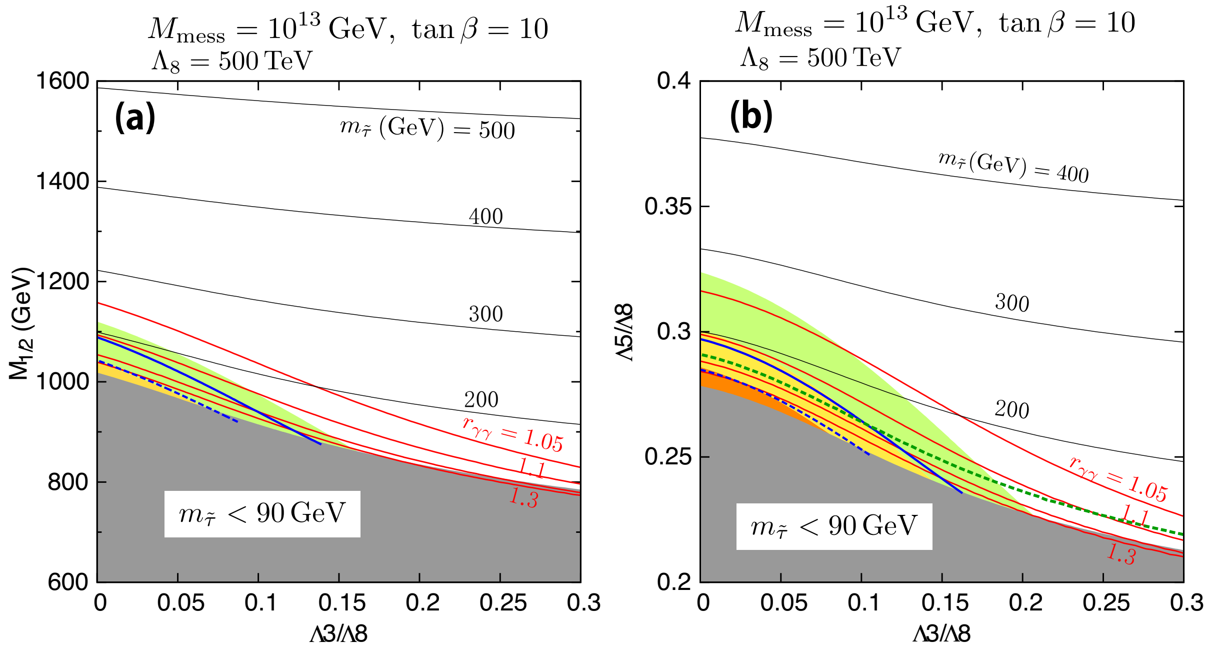

Figure 2: Contours of diphoton decay rate $r_{\gamma\gamma}(= 1.05, 1.1, 1.2, 1.3)$ and the (lighter) stau mass. A common messenger mass $M_3 = M_8 = M_{\rm mess} = 10^{13}$ GeV is assumed, for simplicity. Below the blue solid line the electroweak symmetry breaking minimum is unstable (the blue dashed line has been drawn with a 10% relaxation on $\mu\tan\beta$). The large green shaded region at the bottom is disfavored by the experimental lower limit on the stau mass. In the *left panel (a)*, there is no $\mathbf{5}+\bar{\mathbf{5}}$ messengers and the stau is the NLSP. Here, in the light green (yellow) region, the muon $(g-2)$ is explained at $2(1.5)-\sigma$ level. In the *right panel (b)*, $\mathbf{5}+\bar{\mathbf{5}}$ messengers are included to improve consistency with the muon $(g-2)$ measurement. In this panel, in the light yellow (yellow) (orange) region, the muon $(g-2)$ is explained at $2(1.5)(1.0)-\sigma$ level. Above (below) the green dashed line the neutralino (stau) is the NLSP.

bound on $\mu\tan\beta$ by 10%. In the whole region, the stau is the next-to-lightest supersymmetric particle (NLSP), and the region where $m_{\tilde\tau}$ is below 340 GeV is excluded by the CMS Collaboration for such a long-lived stau (it can decay into a gravitino, but the gravitino mass is of the same order as that of the lighter stau and the coupling is extremely weak) [30]. But 340 GeV mass of the lighter stau is too heavy to explain the diphoton enhancement, and it also implies a little heavier smuon which cannot improve the muon $(g-2)$ discrepancy. The way out is to admit a mild R-parity violation (RPV) which would allow the stau to promptly decay into a tau (or another lepton) and a neutrino, thus invalidating the LHC constraint. Turning on RPV also invalidates the LHC constraint on the chargino mass [6, 7]. For convenience, we work only with the trilinear lepton number violating RPV superpotential as [31]

$$W = k_1 LLE + k_2 LQD\,. \tag{9}$$

We have omitted the flavor indices for simplicity. If we assume $k_1, k_2 \lesssim 10^{-7}$, then baryon asymmetry is not washed out [32]. Note that no other constraint is more stringent than this, and with the couplings of this size, the decay length of stau is estimated as

$$c\tau_{\tilde\tau} = \mathcal{O}(0.1)\,{\rm cm}\left[\frac{(k_1,k_2)}{10^{-7}}\right]^{-2}\left(\frac{m_{\tilde\tau}}{100\,{\rm GeV}}\right)^{-1}, \tag{10}$$

which can be regarded as prompt decay. In this case, we can safely take the stau to be much lighter than 340 GeV, which helps us to enter within 2-σ (at best, 1.5-σ) allowed zone of muon $(g-2)$. Note that with this small size of the lepton number violating couplings, the life-time of the gravitino remains longer than the age of the universe. Therefore, the gravitino still constitutes a very good dark matter candidate [33]. For the sake of illustration, we exhibit in Table. 1 the mass spectrum corresponding to a typical point in the parameter space that explains the muon $(g-2)$ within 2-σ.

Λ_3/Λ_8	0.10	Λ_3/Λ_8	0.10	Λ_3/Λ_8	0.05
Λ_8	500 TeV	Λ_5/Λ_8	0.28	Λ_5/Λ_8	0.27
$M_{1/2}$	920 GeV	Λ_8	500 TeV	Λ_8	500 TeV
$M_{\rm mess}$	10^{13} GeV	$M_{\rm mess}$	10^{13} GeV	$M_{\rm mess}$	10^{13} GeV
$\tan\beta$	10	$\tan\beta$	10	$\tan\beta$	10
μ	5.9 TeV	μ	5.6 TeV	μ	5.6 TeV
$m_{\rm stop}$	8.2 TeV	$m_{\rm stop}$	7.8 TeV	$m_{\rm stop}$	7.8 TeV
δa_μ	1.24×10^{-9}	δa_μ	1.12×10^{-9}	δa_μ	1.86×10^{-9}
$m_{\rm gluino}$	10 TeV	$m_{\rm gluino}$	9.5 TeV	$m_{\rm gluino}$	9.5 TeV
$m_{\rm squark}$	9.4 TeV	$m_{\rm squark}$	8.9 TeV	$m_{\rm squark}$	8.9 TeV
$m_{\tilde{e}_L}(m_{\tilde{\mu}_L})$	601 GeV	$m_{\tilde{e}_L}(m_{\tilde{\mu}_L})$	574 GeV	$m_{\tilde{e}_L}(m_{\tilde{\mu}_L})$	451 GeV
$m_{\tilde{e}_R}(m_{\tilde{\mu}_R})$	258 GeV	$m_{\tilde{e}_R}(m_{\tilde{\mu}_R})$	310 GeV	$m_{\tilde{e}_R}(m_{\tilde{\mu}_R})$	289 GeV
$m_{\tilde{\tau}_1}$	98 GeV	$m_{\tilde{\tau}_1}$	201 GeV	$m_{\tilde{\tau}_1}$	105 GeV
$m_{\chi_1^0}$	315 GeV	$m_{\chi_1^0}$	156 GeV	$m_{\chi_1^0}$	149 GeV
$m_{\chi_1^\pm}$	851 GeV	$m_{\chi_1^\pm}$	557 GeV	$m_{\chi_1^\pm}$	411 GeV

Table 1: Sample mass spectra shown in three vertical blocks. The left block corresponds to the case without the conventional $\mathbf{5}(\bar{\mathbf{5}})$ messengers, where the stau is the NLSP. The right two blocks correspond to the cases including the $\mathbf{5}(\bar{\mathbf{5}})$ messengers. In the second block the lightest neutralino is the NLSP while in the third block the stau is the NLSP.

How can we enter inside the 1-σ allowed zone of muon $(g-2)$? For that we need to give up the minimality of messenger particle content, and add a Φ_5 and a $\Phi_{\bar{5}}$ to the existing Σ_3 and Σ_8, i.e. add to Eq. (1) the following piece [18]

$$W_{\rm mess}^{\rm new} = (M_5 + \lambda_5 X)\Phi_5\Phi_{\bar{5}}\,. \tag{11}$$

This of course does not alter the scale of string unification. But what do we gain by this? In this scenario, bino and right-slepton masses are generated by Φ_5 and $\Phi_{\bar{5}}$ as they have non-vanishing hypercharges (as in conventional GMSB). We can completely ignore the supergravity effects for their mass generation. Importantly, we do not need to make any *ad hoc* assumption regarding the sequestering of Kahler potential. Now we have the freedom of choosing either bino or stau as NLSP (unlike in the previous scenario where stau is necessarily the NLSP). Gravitino is as usual the LSP but it can be much lighter, e.g. $\sim$ 1 GeV, than in the previous case ($\sim$ 10 GeV). In the *right panel (b)* of Fig. 2, we show that contours of $m_{\tilde{\tau}}$, $r_{\gamma\gamma}$ and the muon $(g-2)$. A common messenger scale $M_{\rm mess} = 10^{13}$ GeV has been taken. Above the green dashed line, the neutralino is the NLSP. But if R-parity is conserved, the neutralino NLSP is sufficiently long-lived to contradict bounds from big-bang nucleosynthesis, to avoid which we need a mild RPV interaction. Below the green dashed line the stau is the NLSP, and for such a light stau one again requires a mild RPV interaction. But the price of turning on RPV is compensated as in this region the muon $g-2$ can be explained at 1-σ level. In the second and third vertical blocks of Table 1 we have shown mass spectra of typical points for the neutralino NLSP and stau NLSP scenarios, respectively.

Our scenario predicts the presence of light sleptons and electroweak gauginos which may be observed in collider experiments. In most of the parameter space of our interest, $\tilde{\tau}_1$ is the NLSP and the decay modes of $\tilde{\tau}_1$ can be classified into three categories, e.g., $\tilde{\tau}_1 \to e/\mu + \nu$, $\tilde{\tau}_1 \to \tau + \nu$ and $\tilde{\tau}_1 \to qq'$, depending on the particular form of the RPV operator. Electroweak gaugino production is not negligible and gauginos decay mainly to $\tilde{\tau}_1$. This leads to final states with lepton(s) and missing transverse energy. The CMS collaboration has searched for electroweak gauginos and sleptons in multi-lepton (including τ) plus missing transverse energy final states [7]. So far, the bounds are not strong enough to exclude our scenario. For example, the lower limit on the chargino mass is about 300 GeV if $\tilde{\tau}_1$ decays exclusively to τ. It is expected that 14 TeV LHC can cover most of the parameter space which is consistent with the result of muon $(g-2)$ experiment. However, direct pair production of $\tilde{\tau}_1$ (which is mostly the right-type) and its decay to jets is difficult to be searches at the LHC. Even in that case, $\tilde{\tau}_1$ with the mass up to 250-500 GeV can be discovered at the proposed ILC with center of mass energy (0.5-1.0) TeV.

In conclusion, the present experimental context, especially the discovery of a 125 GeV Higgs-like boson at the LHC, and non-observation of anything else *new* either at the LHC or in other experiments, compels us to have a sincere introspection

of many a scenarios beyond the SM that we have so far been advocating. What about supersymmetry? Does naturalness demand that all superparticles have to be simultaneously heavy? Or, can we still have room for some light superpartners, e.g. sleptons and weak gauginos, with two orders of magnitude mass splitting between them and the squarks and gluino created by a natural dynamics? This is precisely the question we have asked in this paper. Our key observation is that by employing an *unconventional* (i.e. not the conventional **5**-plets) choice of messenger multiplets, namely, a color SU(3) octet and a weak SU(2) triplet with $M_3 > M_8$ in a GMSB setup, we can generate a spectrum that naturally accommodates the required mass splitting between the colored and uncolored superpartners, justifying all current data including the muon $(g-2)$ and also a very moderate enhancement in the Higgs decay width in diphoton mode. What is really elegant about this scenario is that the use of even *incomplete* SU(5) messenger multiplets at an intermediate scale does not disturb a successful unification of the gauge couplings. Depending on the choice of the triplet and the octet messenger masses (still maintaining $M_3 > M_8$), the meeting point moves to a scale slightly higher than that of usual grand unification; and interestingly, the new scale can, in fact, be the string scale where the gauge and gravitational couplings are perturbatively unified [20]. Thus, perturbative string unification, intermediate scales characterizing GMSB messengers, and the relative lightness of sleptons and weak gauginos compared to the squarks and the gluino, are all interlinked by a single underlying dynamics. This scenario is testable, as these uncolored superpartners can be discovered (or excluded) at the 14 TeV LHC or at the ILC.

Acknowledgements: G.B. thanks Kavli IPMU for hospitality when the work was done. N.Y. thanks S. Sugimoto for useful discussion. We all thank M. Ibe and S. Matsumoto for discussions at the early stage of this work. The work of N.Y. is supported in part by JSPS Research Fellowships for Young Scientists. This work is also supported by the World Premier International Research Center Initiative (WPI Initiative), MEXT, Japan.

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